Validation of multibeam acoustic classification by benthic imagery near Grosse-Île, Îles-de-la-Madeleine, Québec

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ABSTRACT

Larocque, R., M.-N. Bourassa, and C. Savenkoff. 2012. Validation of multibeam acoustic classification by benthic imagery near Grosse-Île, Îles-de-la-Madeleine, Québec. Can. Ind. Rep. Fish. Aquat. Sci. 288: v + 25 p.

In response to uncertainties regarding the nature of bottom sediments in a mixed fisheries area, an imagery survey was undertaken north of Grosse-Île (Îles-de-la-Madeleine, Quebec) as ground-truthing for existing multibeam acoustic data. Digital stills from video cameras were used to establish bottom types in contentious areas, and the resulting classification was the basis for recommendations that allowed the coexistence of a lobster fishery and mobile-gear-based flatfish and mollusc fisheries. The project demonstrates how low-cost bottom imagery surveys can be used to validate data collected using other methods.

RÉSUMÉ

Larocque, R., M.-N. Bourassa, and C. Savenkoff. 2012. Validation of multibeam acoustic classification by benthic imagery near Grosse-Île, Îles-de-la-Madeleine, Québec. Can. Ind. Rep. Fish. Aquat. Sci. 288: v + 25 p.

En réponse à des incertitudes au sujet de la nature des sédiments benthiques dans un secteur de pêcheries mixtes, un relevé par imagerie a été réalisé au nord de Grosse-Île (Îles-de-la-Madeleine, Québec) pour valider des données acoustiques multifaisceaux existantes. Des saisies numériques provenant de caméras vidéo ont été employées pour établir la nature des fonds dans les secteurs litigieux et sont à la base de recommandations qui permettent la coexistence de la pêche au homard et de pêches à la plie côtière et aux mollusques utilisant des engins mobiles. Ce projet démontre l'utilité des relevés d'imagerie benthique peu coûteux pour valider l'information obtenue d'autres sources.

1. INTRODUCTION

1.1. Previous work and objectives

Conflicts between inshore clam and flounder fishermen and lobster fishermen led the district office of the Department of Fisheries and Oceans Canada (Îles-de-la-Madeleine, Quebec) to request the help of DFO Science (Quebec region). Lobster and Atlantic surfclam habitats were identified and geo-located. A multibeam acoustic survey was conducted in 2010 by the Canadian Hydrographic Service (CHS) using two vessels, the *F. G. Creed* for the offshore portion and the *Guillemot* for near-shore areas. The multibeam data was analyzed, and the backscatter component (a proxy for bottom hardness) was classified and used in combination with fisheries data to establish areas where the use of mobile gear and hydraulic dredges would be acceptable. The resulting map (Figure 1) and recommendations were published in 2011 (MPO, 2011) as part of the Regional Science Special Response Process (SSRP), in time for the 2011 fishing season.

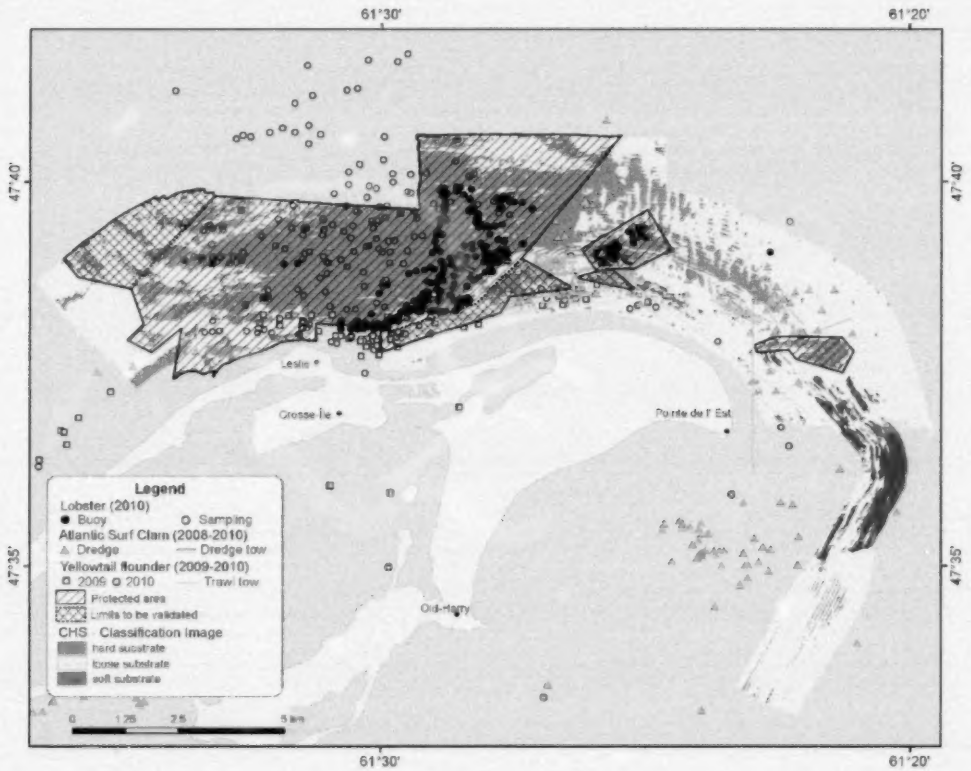

Figure 1. Substrate classification and protected areas as established by DFO (2011).

This assessment also identified areas where the fisheries data and the backscatter classification were in conflict. These were labelled "to be validated" and tentatively marked as off-limits to mobile gear. The district office again requested that DFO Science assess the nature of the sediments in these areas.

A simple ground-truthing project was undertaken to address these uncertainties. A method relying on video imagery and a "drop-cam" system was selected due to its simplicity, ease of use on vessels of opportunity, and the extensive experience of our group in using these techniques efficiently.

The general objective was to aquire images of as many individual point sites as possible within the two-day time frame allocated. Sediment and bottom types were to be identified from the imagery and the results would be used as the basis for new usage recommendations. The imagery was also to be made available to the stakeholders for future reference, both as part of this report and using online geographic applications.

2. MATERIALS AND METHODS

2.1. Site selection and navigation

Three areas to be validated were previously identified in the Science Response document (MPO, 2011) that led to this work. Two additional areas were included following a recommendation by the regional (Îles-de-la-Madeleine, Quebec) DFO office (Figure 2). Within these areas, an arbitrary number of sampling sites were selected based on the available information on bottom types and on specific management issues identified by DFO. Two "hard bottom" control sites were also added to confirm the nature of what was believed to be a hard sandstone substrate. All sampling and camera work was done using a chartered 11.5 m fishing vessel on September 26 and 28, 2011.

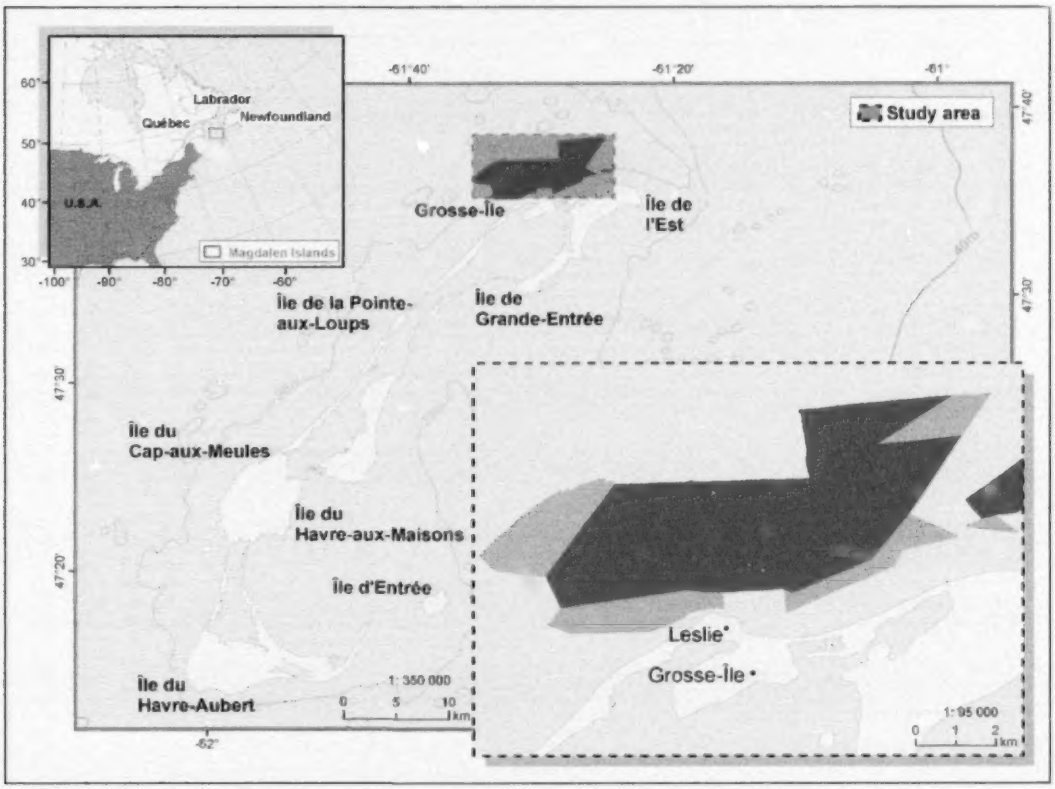

Figure 2. The Grosse-Île study area is located in the northern part of the Îles-de-la-Madeleine. The five areas that were examined are shown in pink.

2.2. Sediment sampling

Surface sediment samples were collected on a limited number of sites using a Shipeck grab (Wildlife Supply Co., Yulee, FL, USA). The grab contents were transferred to a large plastic container and photographed. A short white ruler was positioned in the frame as a size reference. Notes on the organisms, on the type of sediments, and on total sample volume were taken. The samples were then discarded. The grab samples were used only for a qualitative assessment of the bottom type as an extra validation of the information gathered from bottom imagery.

2.3. Equipment, image acquisition, and data logging

A metal frame measuring 1.02 m (h) × 0.71 m (l) × 0.97 m (d) was used to support two video cameras and a lighting system (Figure 3). The frame had no electrical or data connection to the surface. It was moved from the deck of the vessel and lowered to the bottom using a 3/8 in. rope and a regular hauler (crab block). Total weight was approximately 60 kg.

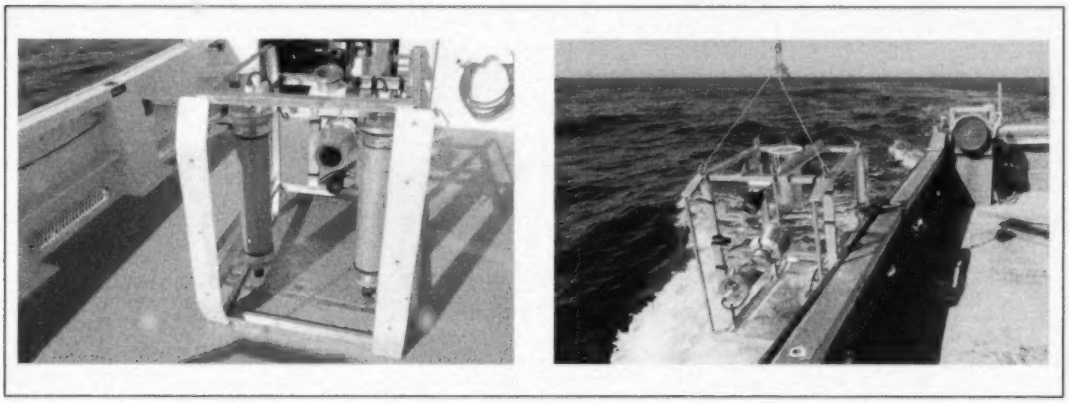

Figure 3. Drop-cam system with two cameras and lights. A view from under the frame (left) and ready for deployment (right).

Two cameras were used: 1) A downward-looking camera (Canon HV-20 HDV 1080i) inside a pressure housing fitted with an acrylic flat port, and 2) a second camera (Sanyo FH1, 1080p), also in a pressure housing, positioned on one side of the frame at a 30° angle from the horizontal plane. The vertical camera imaged an area of approximately 0.65 m^2 with a 16:9 aspect ratio while the second one provided an image approximately 1.30 m wide at the nearest point. Both cameras were equipped with additional wide-angle lenses to compensate for the narrow field of view associated with flat ports. Recording was started at the surface before closing the ports and stopped after five or six dives to replace the batteries, MiniDV tape and memory card.

Each camera's field of view was illuminated using one 45 watt LED wide-angle projector (Deep Sea Power & Light) powered by a 24V battery pack. The lights were controlled by an immersion detection system. Because of the shallow depths, water clarity, and the sun's illumination, ambient light was generally dominant in the images.

A portable GPS (Garmin, GPSmap 60CSx) unit was used to log the vessel's track at one-second intervals for the full duration of each work day. The GPS was used in WAAS differential mode for greater accuracy. The NMEA data feed from the GPS was also used on a live map (Global Mapper v.12) for navigation and to document the exact position of the sampling stations. A point was saved at the exact moment when the frame touched the bottom. The saved track in GPX format was later used to geo-tag all imagery, including topside photos.

2.4. Image geo-coding and processing

The video captured on miniDV tape using the vertical camera was viewed on a monitor connected directly to the camera. For each site, one clear video frame was captured in full resolution to the camera's internal flash card. This ensured that the time and date metadata would be preserved in the file's EXIF header. The other camera recorded in MPEG-4 format on a flash card. The files were viewed using Videolan VLC Media player (ver. 1.1.11), and frames were captured directly to the computer. Since this format does not include time and date information, these were added manually to the EXIF headers. The image management procedures follow the best practices recommendations from Nozères (2011).

All the resulting JPEG 1920 × 1080 pixel image files were geo-tagged using RoboGeo (ver. 6.3.2) to look up the geographic information from the track logs with time as the common reference. Latitude and longitude were automatically added to the EXIF headers of all files. The image files were imported into Adobe Lightroom 3.6 for easier management and for enhancement.

All images were colour-corrected to provide a pseudo-natural colour balance, which involved removing the blue-green cast. Vignetting was removed when required, contrast and low-level details were enhanced, and the final enhanced versions were exported for analysis.

2.5. Image analysis

The vertical images were imported into Adobe Photoshop (ver. CS4) where a red grid with 50 intersections was overlaid (Figure 4). The same procedure was used with the oblique images, but the grid was perspective-corrected to provide 184 intersections (Figure 4). The resulting images were then analyzed to estimate the occurrence of three particle grain sizes. The categories (0–2 mm = fine; 2–64 mm = intermediate; > 64 mm = large) were based on cut-off points in the standard Wentworth scale (Folk, 1974). The grain size of the sediment located immediately under each intersection was identified. If the point was out of focus, or if it was otherwise difficult to characterize, it was marked as a missing value. The relative proportion of each grain size was considered as a proxy of surface coverage. The information from both cameras was processed separately; priority was given to the oblique camera, with the second camera confirming results when more details were required. During analysis, qualitative information was also noted

to document image quality, and biology, and to provide a subjective description of the environment (e.g., "sandy bottom with abundant shell debris, 8 sand dollars visible").

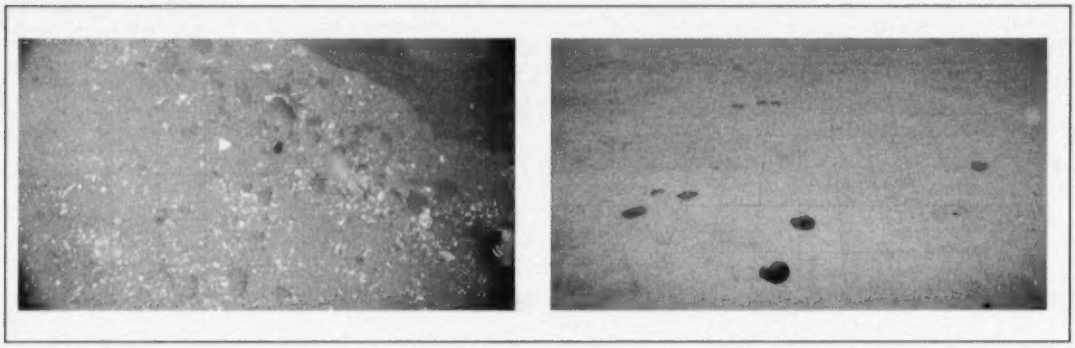

Figure 4. Typical vertical (left) and oblique (right) images (with grid overlays).

2.6. Classification and interpolation

Image analysis provided a grain size distribution according to three categories. Each category was spatially interpolated using an inverse distance weighted (IDW) technique (Spatial Analyst, ArcGIS 9.2). These three layers were used to create the final classification using a scheme similar to Shepard's triangle (Shepard, 1954), where the contribution of each category is used to determine in which of ten potential classes each point falls. This calculation was done with the Map Algebra function of ArcGIS 9.2.

2.7. Bathymetry and backscatter processing

The original Canadian Hydrographic Service (CHS) survey data was re-examined for the specific needs of this project and a 2 m grid was created from the original data. This new grid was used to derive new slope and rugosity maps. Both derivatives are scale-dependent. Slope is expressed in degrees and rugosity has no unit. Rugosity is the ratio of the actual surface area of the sea bottom to the geometric surface area. Slope was derived using the Surface Analysis tool (Spatial Analyst package) and rugosity calculated with NOAA's Benthic Terrain Modeler (BTM) module, both with ArcGIS 9.2.

Backscatter was reprocessed to remove line artifacts and to better adjust the data from the two survey vessels and multibeam systems using the Geocoder tool within Caris/HIPS (ver. 7.0, SP2). The resulting map is better suited to visual interpretation but contains a small number of blank lines where new, more stringent quality criteria could not be met.

3. RESULTS AND DISCUSSION

The two days of field work yielded 66 discrete validation sites with usable oblique and vertical bottom imagery (Figure 5). Two additional sites were also visited to examine what had been classified as "hard" bottoms (inside the central zone in Figure 5). All the enhanced oblique imagery is available in Appendix 1.

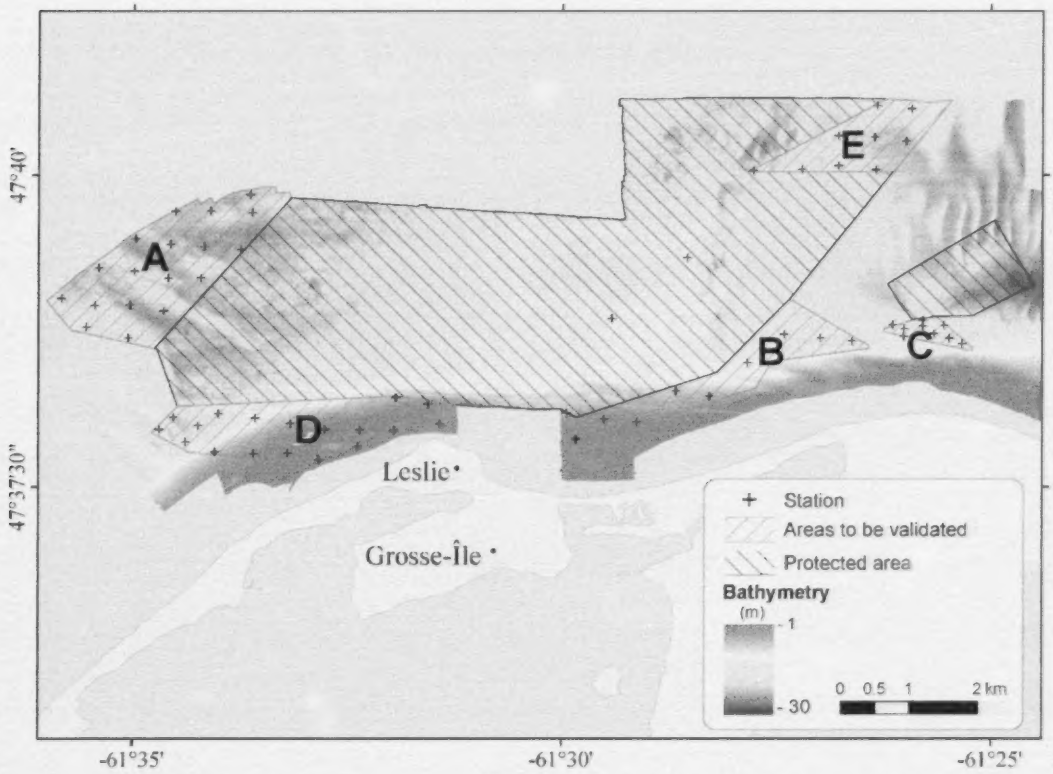

Figure 5. Map of the sector of interest showing the areas (labelled A to E) to be validated, the imagery stations, and bathymetry.

Of the 17 grab samples in area A, 14 provided samples that could be described and photographed. Typical samples are shown in Figure 6. After comparing the grab samples with imagery from the same sites, we concluded that the grabs did not provide significant additional information and no further grab samples were collected outside of area A.

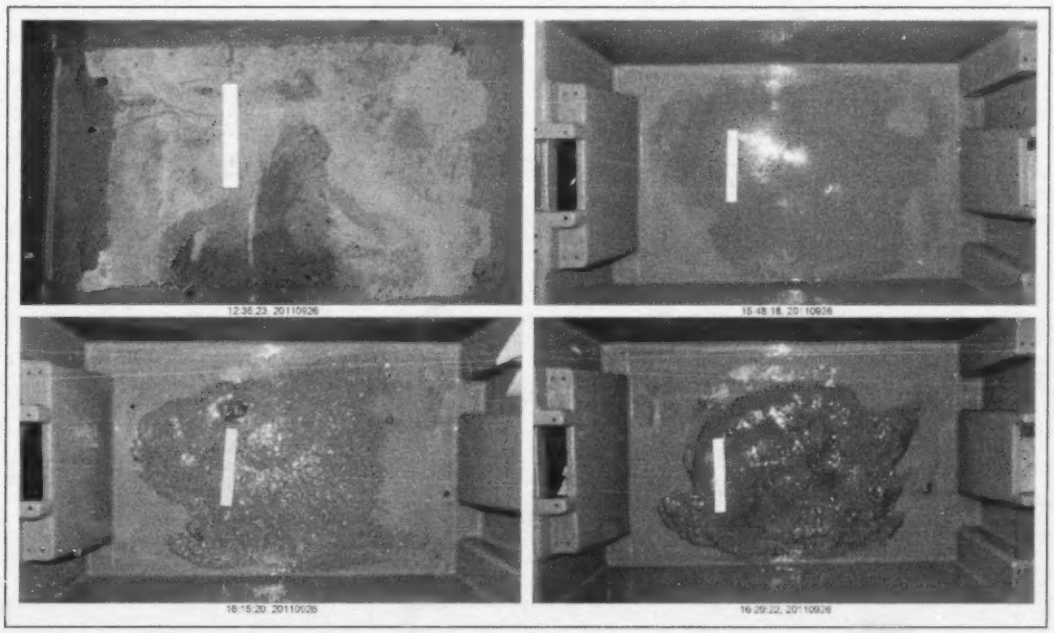

Figure 6. Typical contents of Shipeck grab in area A. The white ruler is 15 cm.

Presenting the sediment composition as simple pie charts for each site provides an effective overview of the information extracted from the oblique imagery (Figure 7). Spatial interpolation of the same data followed by a classification based on composition allows the creation of a continuous surface map (Figure 8) that is useful for management purposes. However, the resulting map must be used with care as the calculated limits of each sediment class may not always be accurate. As an example of these limitations, a shallow reef visible in Figure 5 in area D was not sampled and therefore does not appear in the sediment map.

Reprocessing the backscatter data removed several artifacts and improved the contrast between high and low reflectivity areas (Figure 9). The adjustments between the two surveys also result in a more continuous surface. The highly reflective portion in area B is still visible, but the slope and rugosity data (Figures 10 and 11) confirm that this is unlikely to be a rocky substrate. This information is confirmed by the imagery data, and the most likely conclusion is that hard packed sand may lead to strong echoes that can be misinterpreted if backscatter is used on its own without validation by other methods. A similar situation is visible in area A, where the bathymetry derivatives agree better with actual bottom composition than with backscatter. In area E, the imagery data confirmed the presence of sand and helped locate the edge of the rocky area that characterizes the middle section of the study area. It is suspected that the sand area extends further south, but the limited number of sites that were examined prevents such an extrapolation.

When this type of information is used in a decision-making process, the user must take great care to examine all data sources and find the most likely composition, especially when confronted with contradictory information.

Multibeam surveys provide valuable scientific information that goes beyond the basic bathymetry required for marine charts. Its value is further increased when it is coupled with direct observations of bottom sediments. Taking grab or core samples have historically been the methods of choice for ground truthing acoustic surveys. In our study, a relatively simple imaging technology method has proved to be a cost-effective and time-efficient alternative. Its use has removed most of the uncertainties associated with an earlier survey while providing decision makers and fishing communities with direct observations of their fishing grounds.

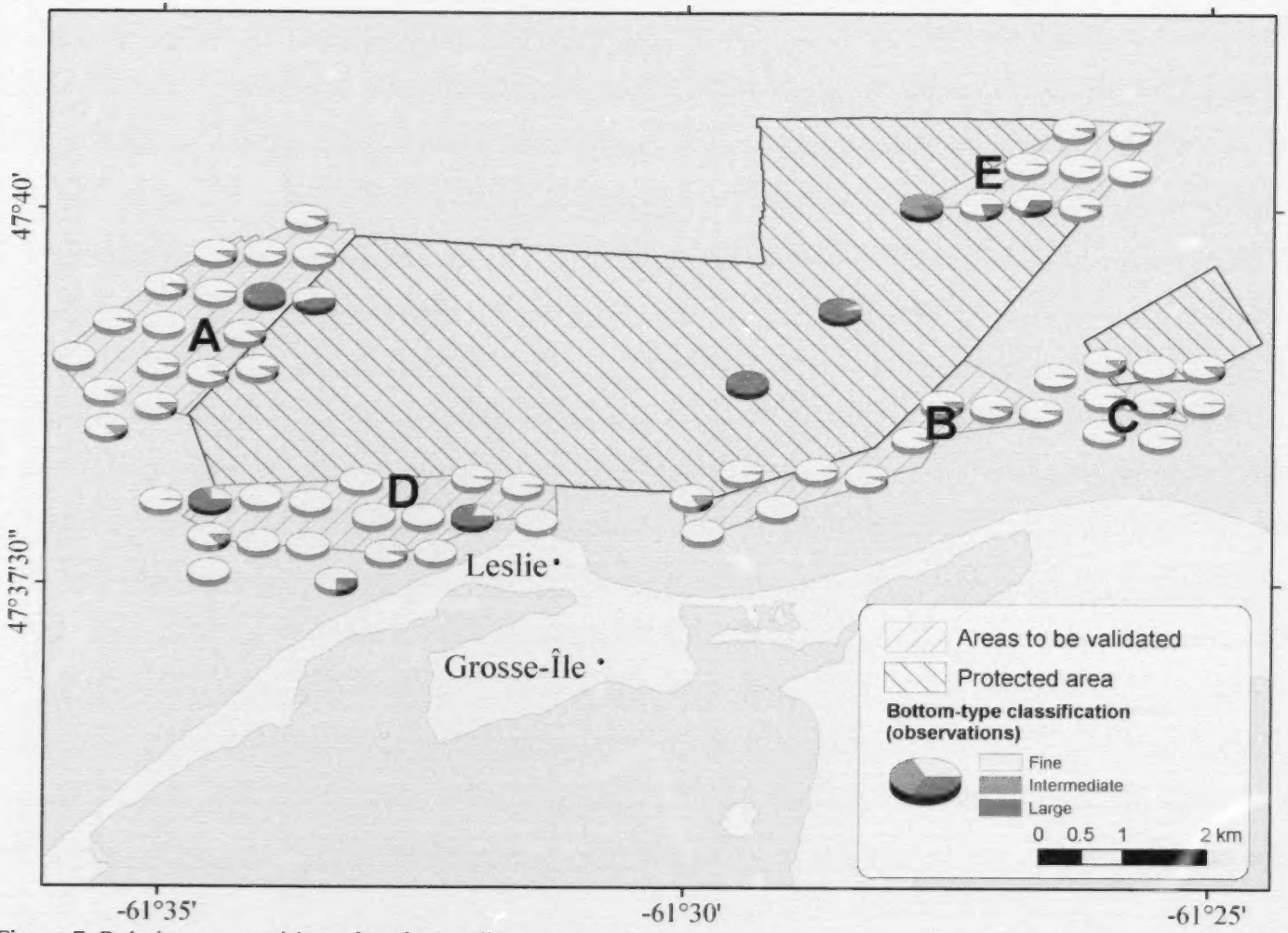

Figure 7. Relative composition of surface sediments at each site.

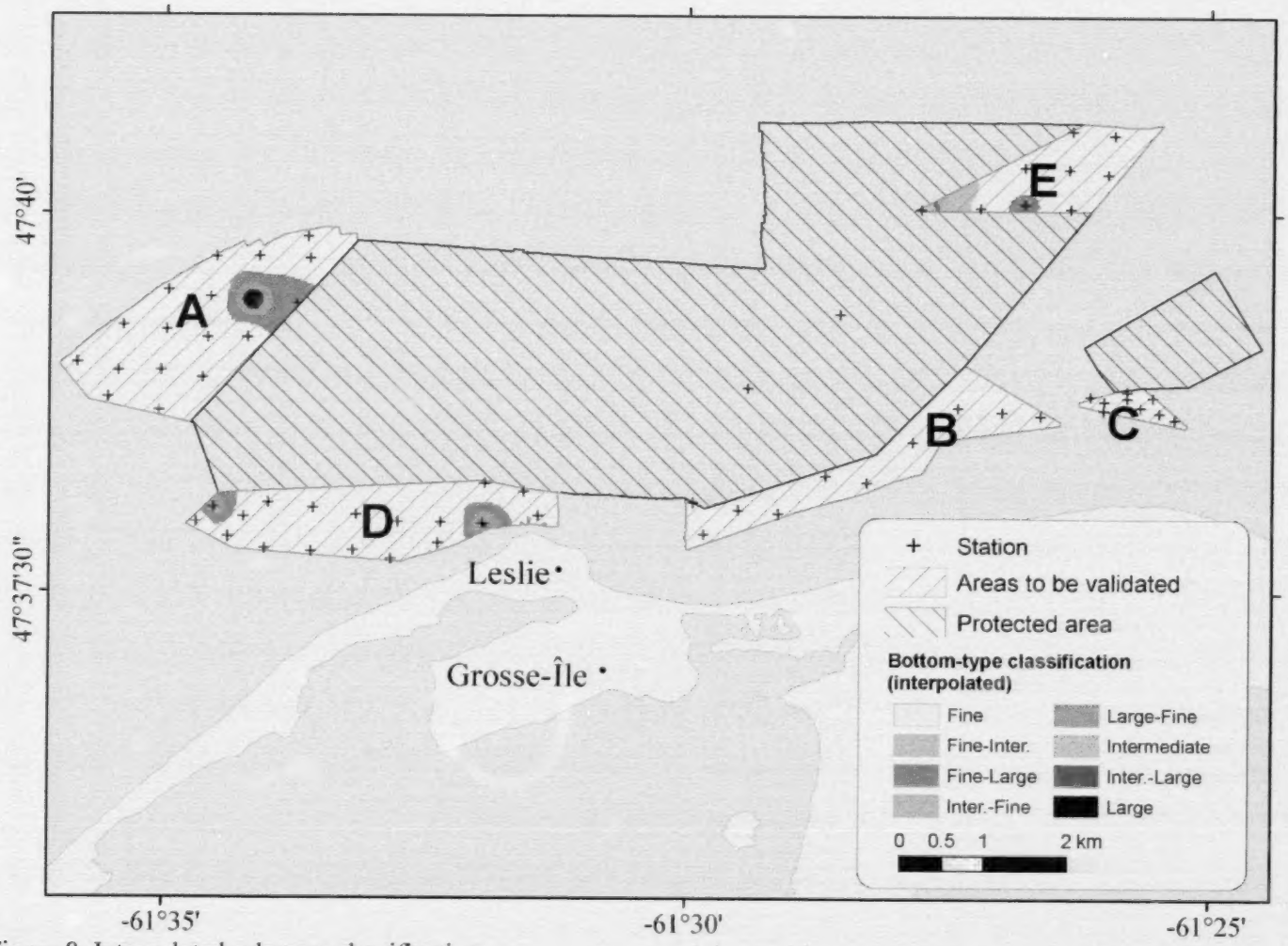

Figure 8. Interpolated substrate classification.

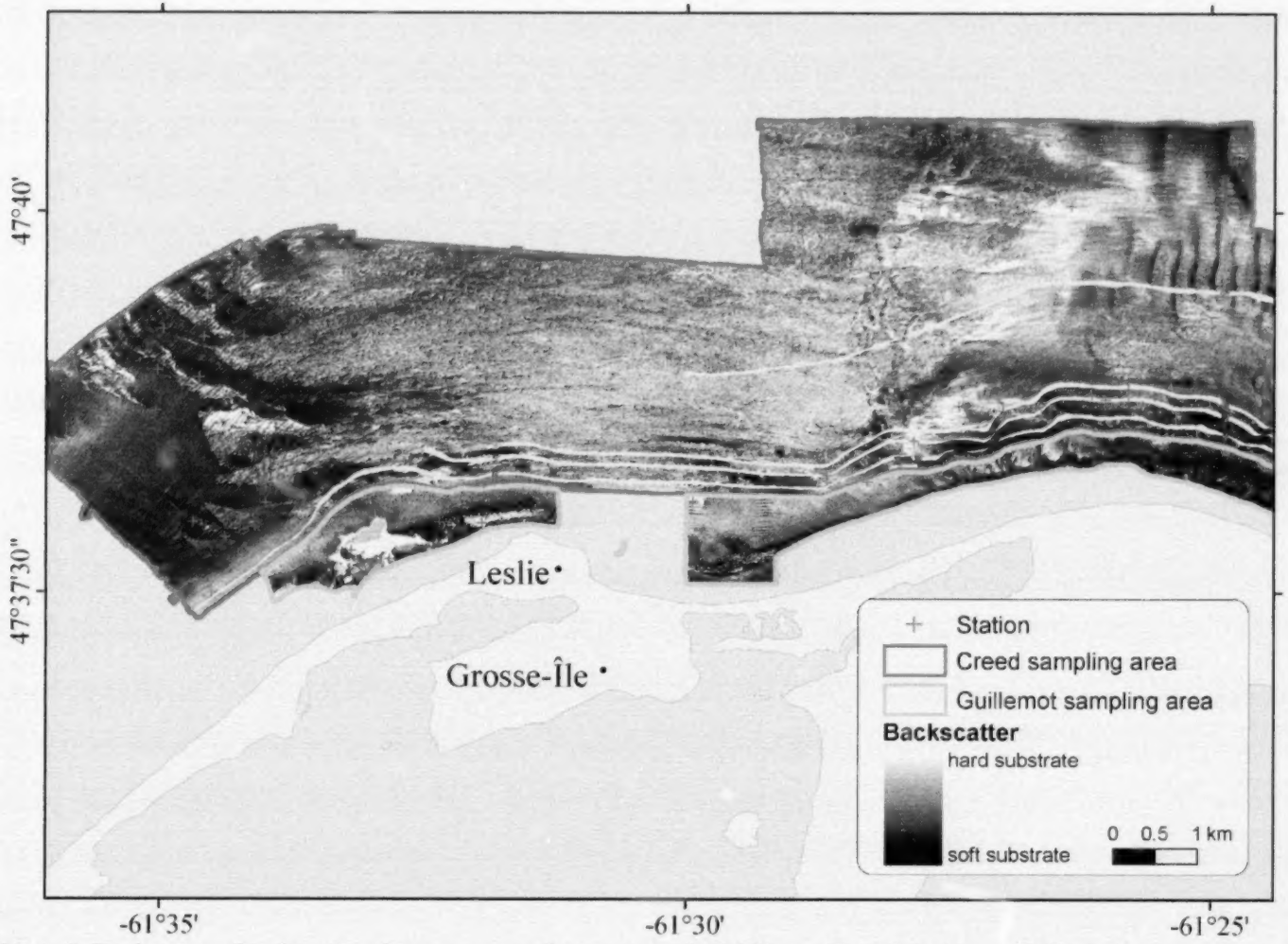

Figure 9. Backscatter (hardness) and survey areas for two vessels (offshore: *Creed*; inshore: *Guillemot*).

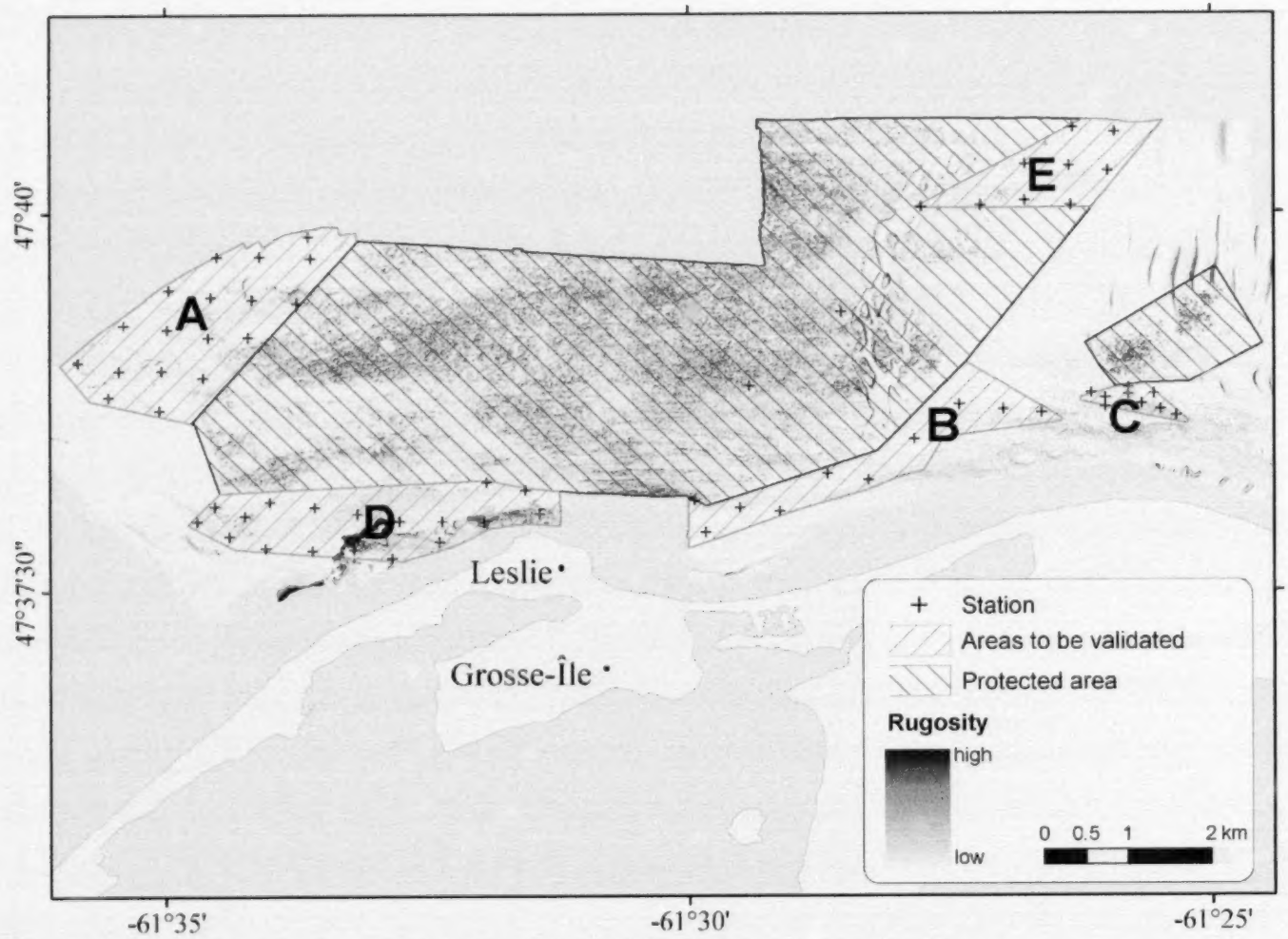

Figure 10. Rugosity (actual area / geometric area) derived from a 2 m bathymetric grid.

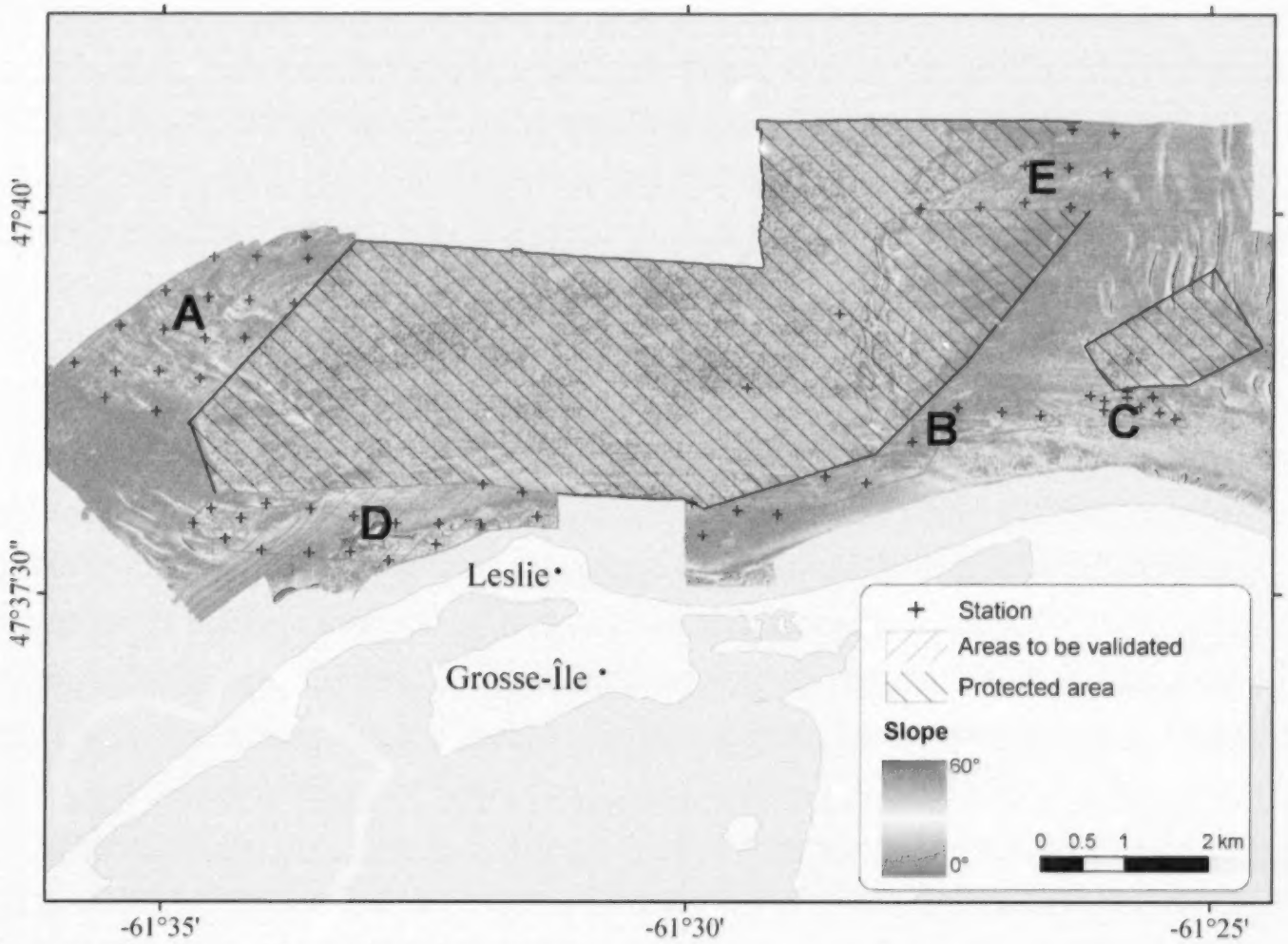

Figure 11. Slopes derived from a 2 m bathymetric grid.

4. RECOMMENDATIONS

Of the three areas identified as requiring validation, all except area A consisted of sand or sand with shell debris. Within area A, two sites had either a hard substrate or sandstone covered by a thin layer of sand. It is recommended that a square area containing these sites be added to the exclusion (from mobile gear) area (in blue, Figure 12).

Area E is mostly sand with the exception of three sites. We can also say with a high degree of confidence that the small area immediately to the north is also sand. Thus, it is recommended that the existing protected area be reduced in size in that sector (in yellow, Figure 12).

A small area located east of the Grosse-Île harbour should also be subtracted from the protected area as no hard substrate was found in the two sample sites. Finally, the southern portion of area D should also change status since only sand was found south of the shoals.

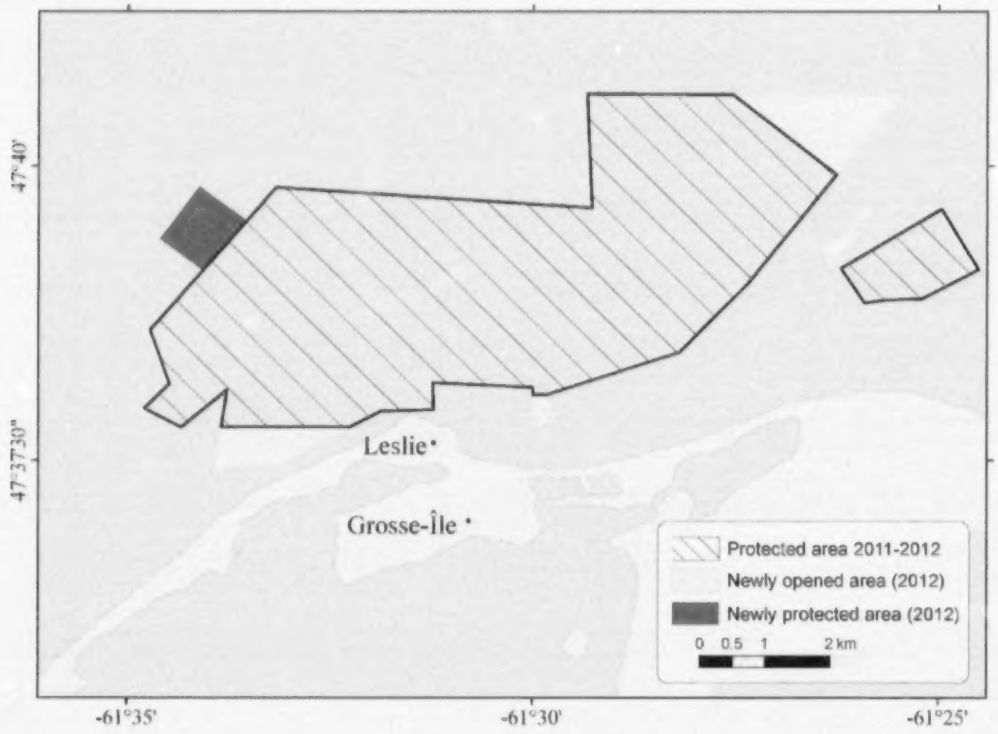

Figure 12. Recommended modifications for mobile gear and lobster fishing areas based on imagery results.

These recommendations are summarized in Figure 12. and the limits are listed in Table 1. These include a 50 m buffer zone outside of the protected area. The buffer zone is intended to prevent overlap between fisheries and as an additional protection measure for hard substrates.

Table 1. Geographic positions of points (defining a polygon) of the newly recommended protected area (NAD-1983).

Latitude (Y)	Longitude (X)	Latitude (Y)	Longitude (X)
47.665474	-61.437608	47.629694	-61.572306
47.650139	-61.455723	47.632360	-61.579805
47.640350	-61.469856	47.635834	-61.574722
47.634320	-61.497136	47.643444	-61.578667
47.634320	-61.500084	47.651847	-61.567921
47.635389	-61.500084	47.656341	-61.576885
47.636028	-61.520527	47.663838	-61.568651
47.632195	-61.520445	47.658929	-61.558860
47.632000	-61.531250	47.663639	-61.552834
47.629751	-61.537651	47.660749	-61.487888
47.629739	-61.564077	47.676971	-61.488916
47.635000	-61.562834	47.676873	-61.458943

The authors wish to reiterate the general recommendation that when multibeam acoustic surveys are to be used as a primary source of data in ground fisheries, validation by direct methods, and preferably by bottom imagery, should be included in the survey plan from the onset.

5. ACKNOWLEDGEMENTS

Arnaud Mosnier provided expert guidance for the image classification work. Claude Nozères was consulted numerous times to make sure our digital assets management strategies were adequate. The Îles-de-la-Madeleine sector office (Christian Houle and staff) secured funding for ship time. The contributions of Steve Burke (owner/operator of the *Sarah J II*) and Jean-Claude Richard (DFO, Conservation and Protection) are graciously acknowledged and were essential for the success of the field work. Selma Pereira, Louise Gendron, and Sylvie Brulotte also provided expert advice on several aspects of this project. The final version of this document was reviewed by Laure Devine. Funding was provided by the Fisheries Science Collaboration Program (FSCP).

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Shepard, F. P., 1954. Nomenclature based on sand-silt-clay ratios: J. Sediment. Petrol. 24: 151–158.

APPENDIX 1. BOTTOM IMAGERY FOR ALL SITES

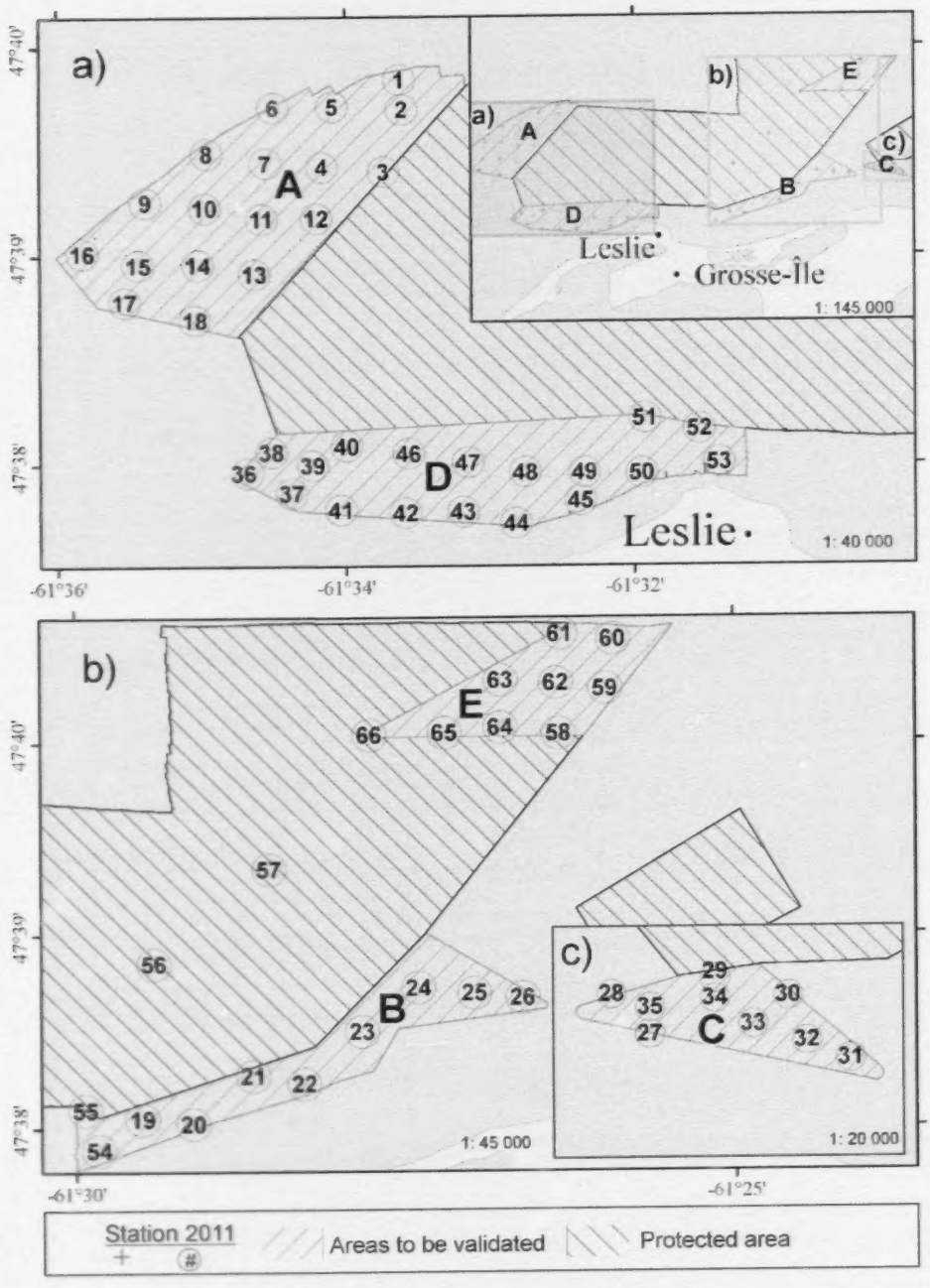

Figure 13. Key to images for all sites.

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Figure 14. Control sites for hard substrate (with station ID numbers) typical of the protected sectors in the study area.

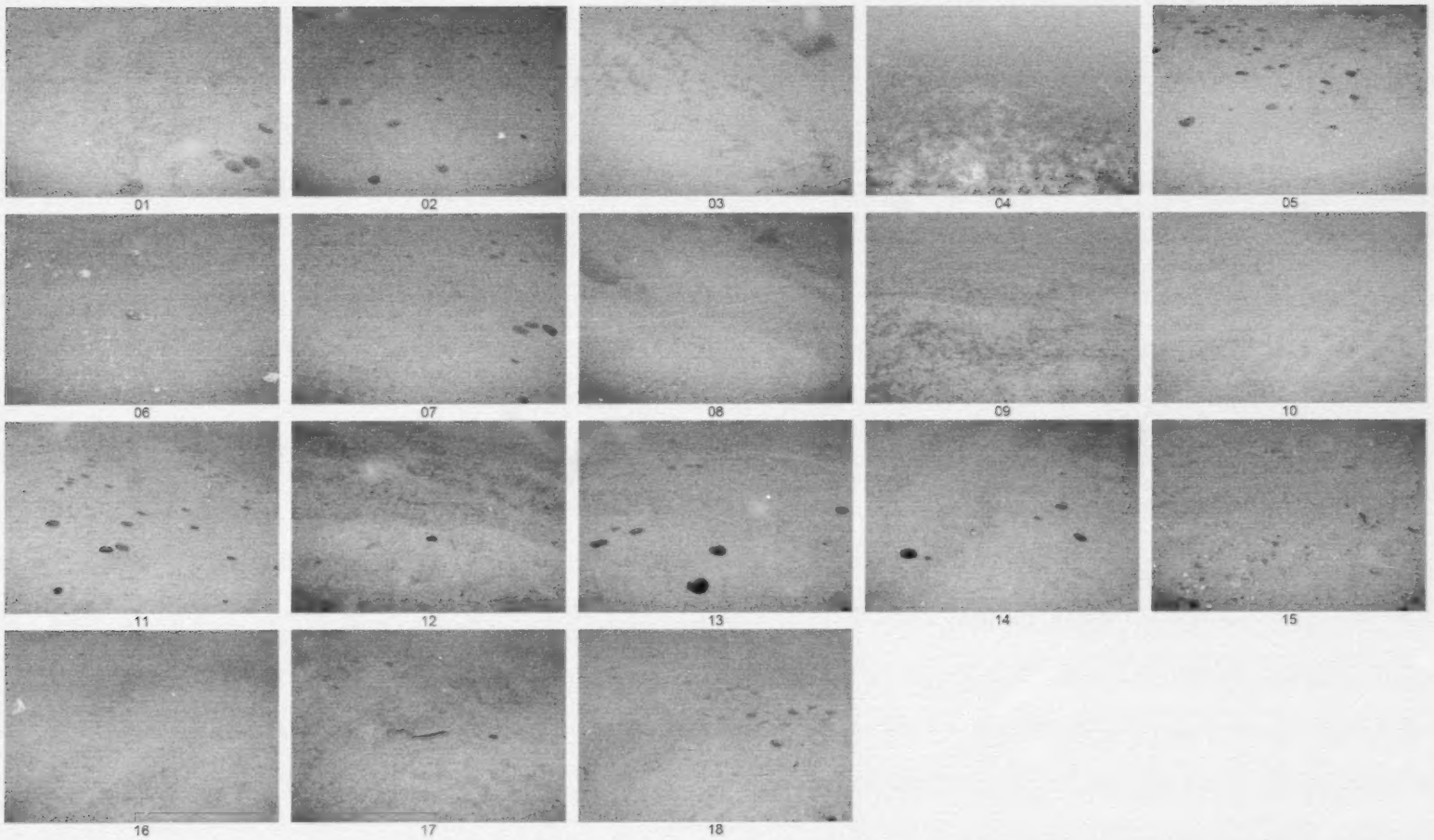

Figure 15. Bottom oblique imagery for area A. Images 03 and 04 show a hard substrate partially covered with sand. Image width-to-length ratios have been adjusted to fit the page.

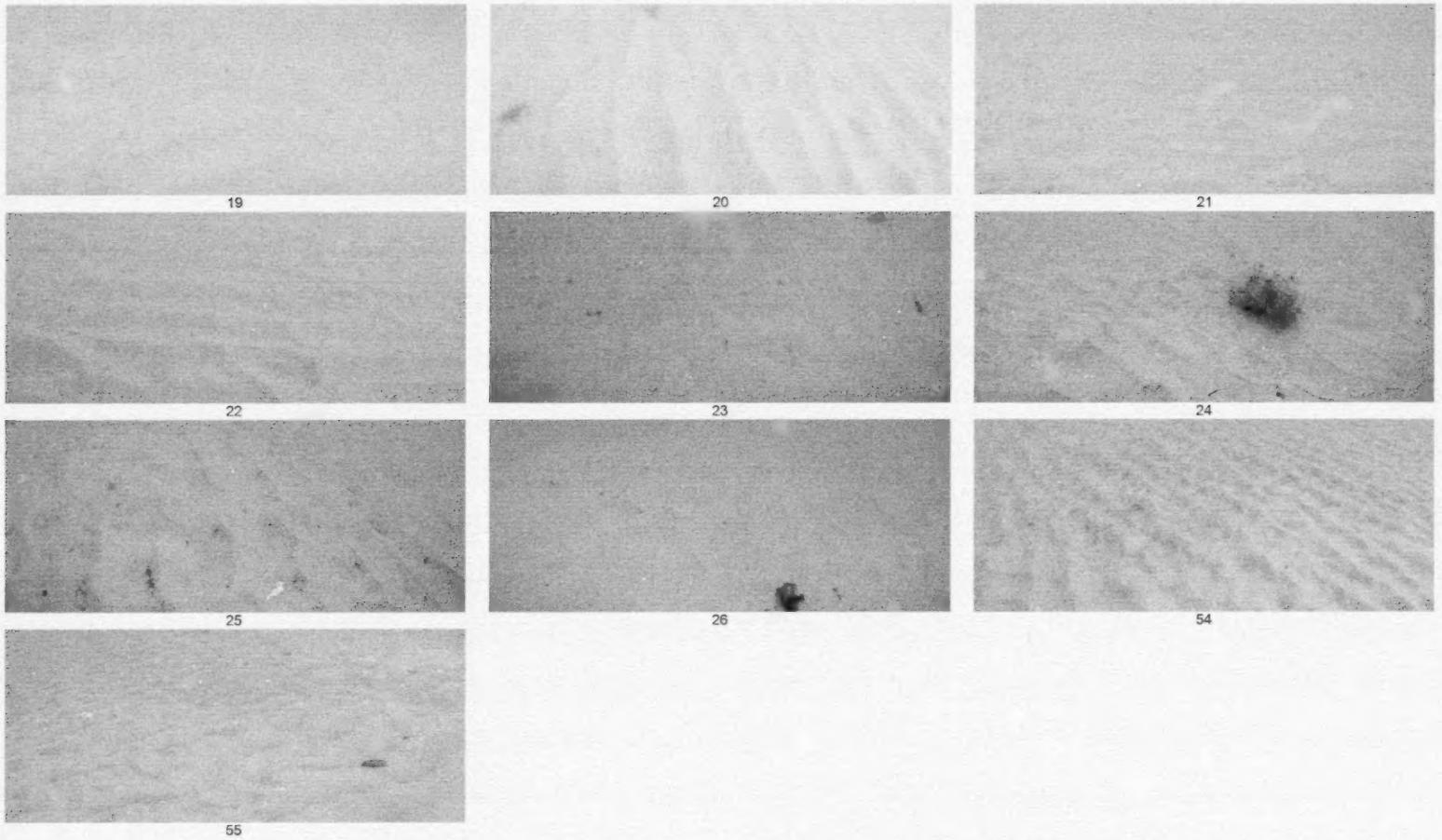

Figure 16. Bottom oblique imagery for area B. All images show sand with small amounts of shell debris. Image width-to-length ratios have been adjusted to fit the page.

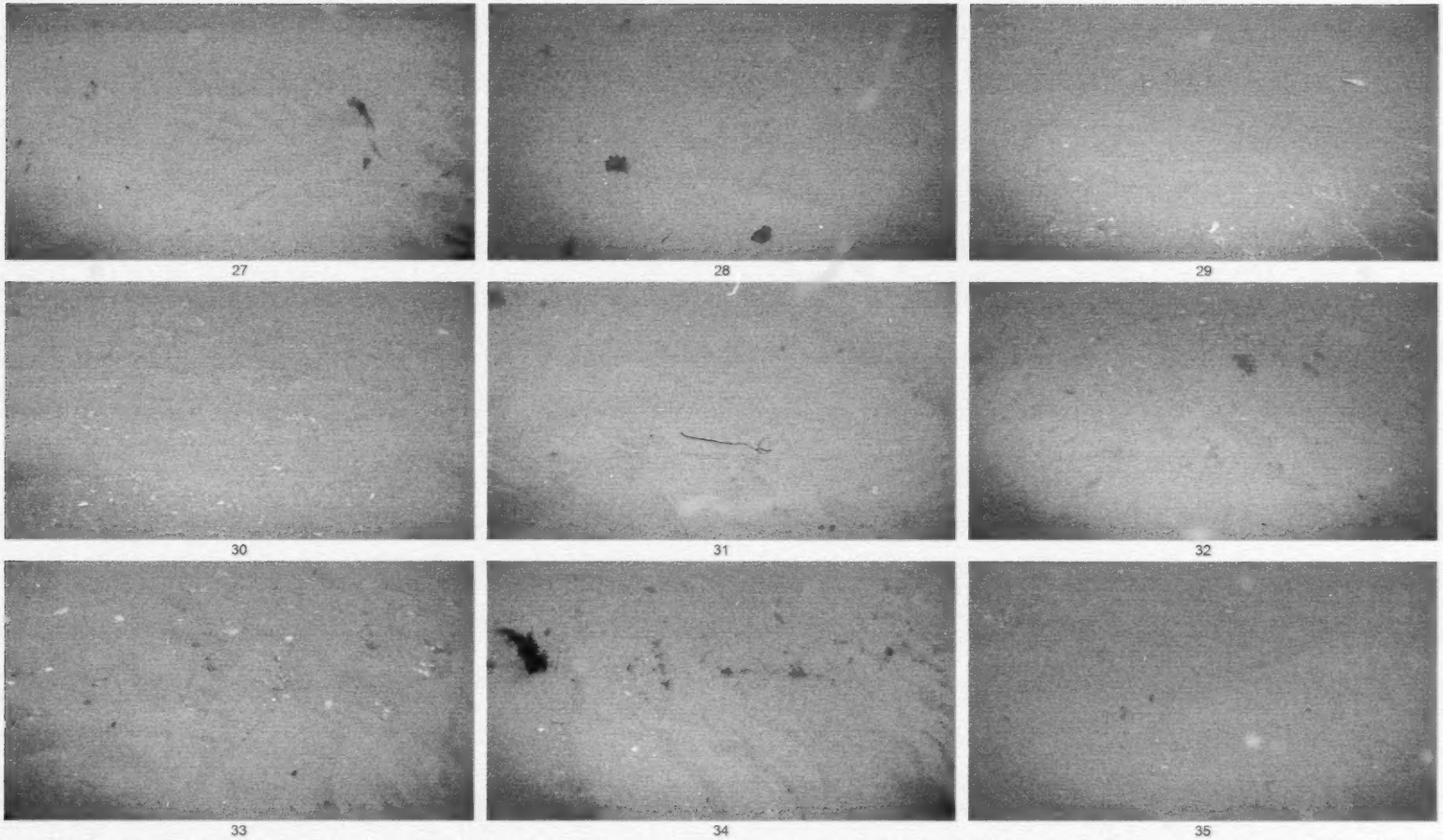

Figure 17. Bottom oblique imagery for area C. All images show sand with moderate amounts of shell debris. Image width-to-length ratios have been adjusted to fit the page.

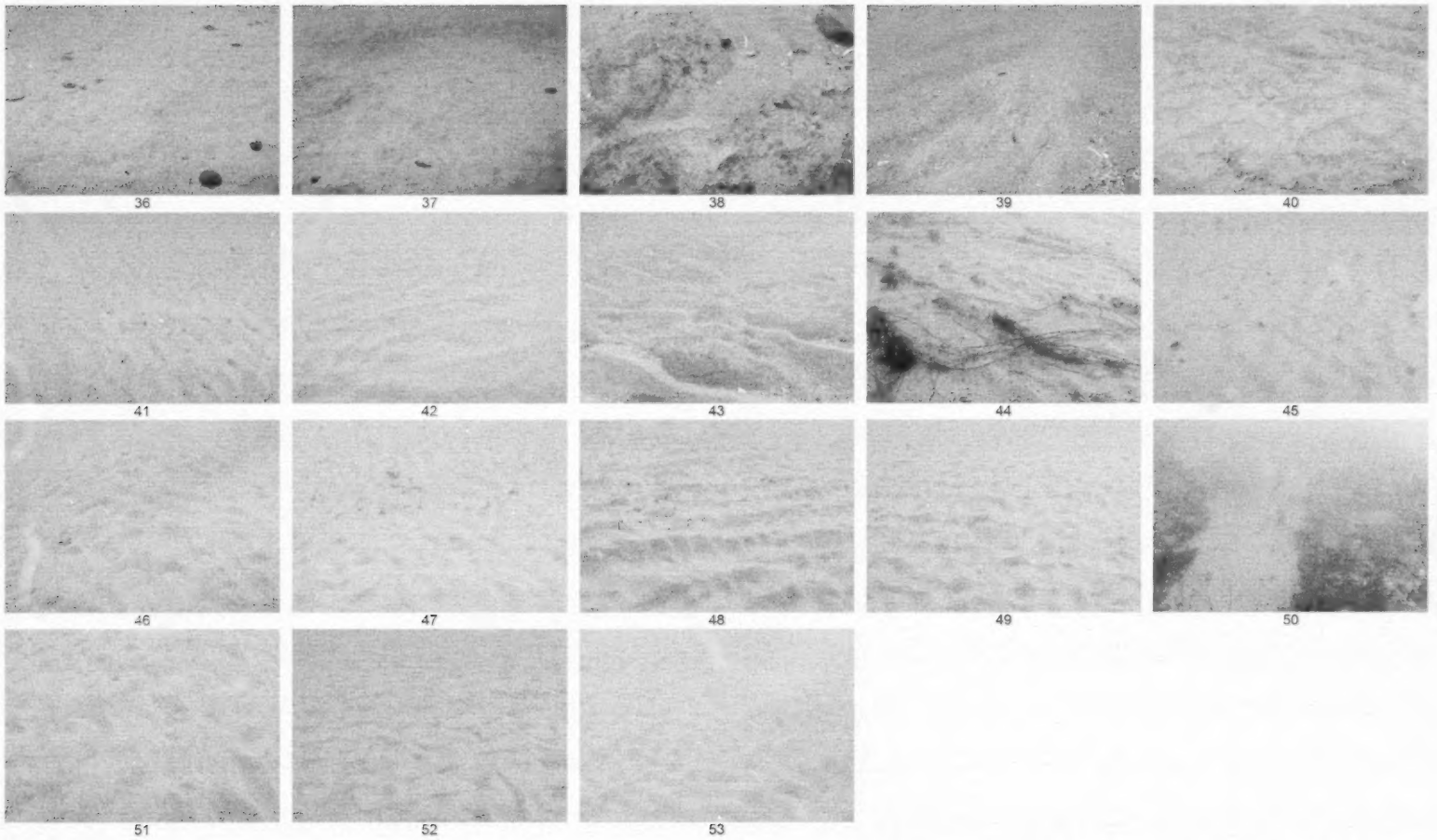

Figure 18. Bottom oblique imagery for area D. Images 38, 43, and 50 show a hard substrate overlaid by sand. Image width-to-length ratios have been adjusted to fit the page.

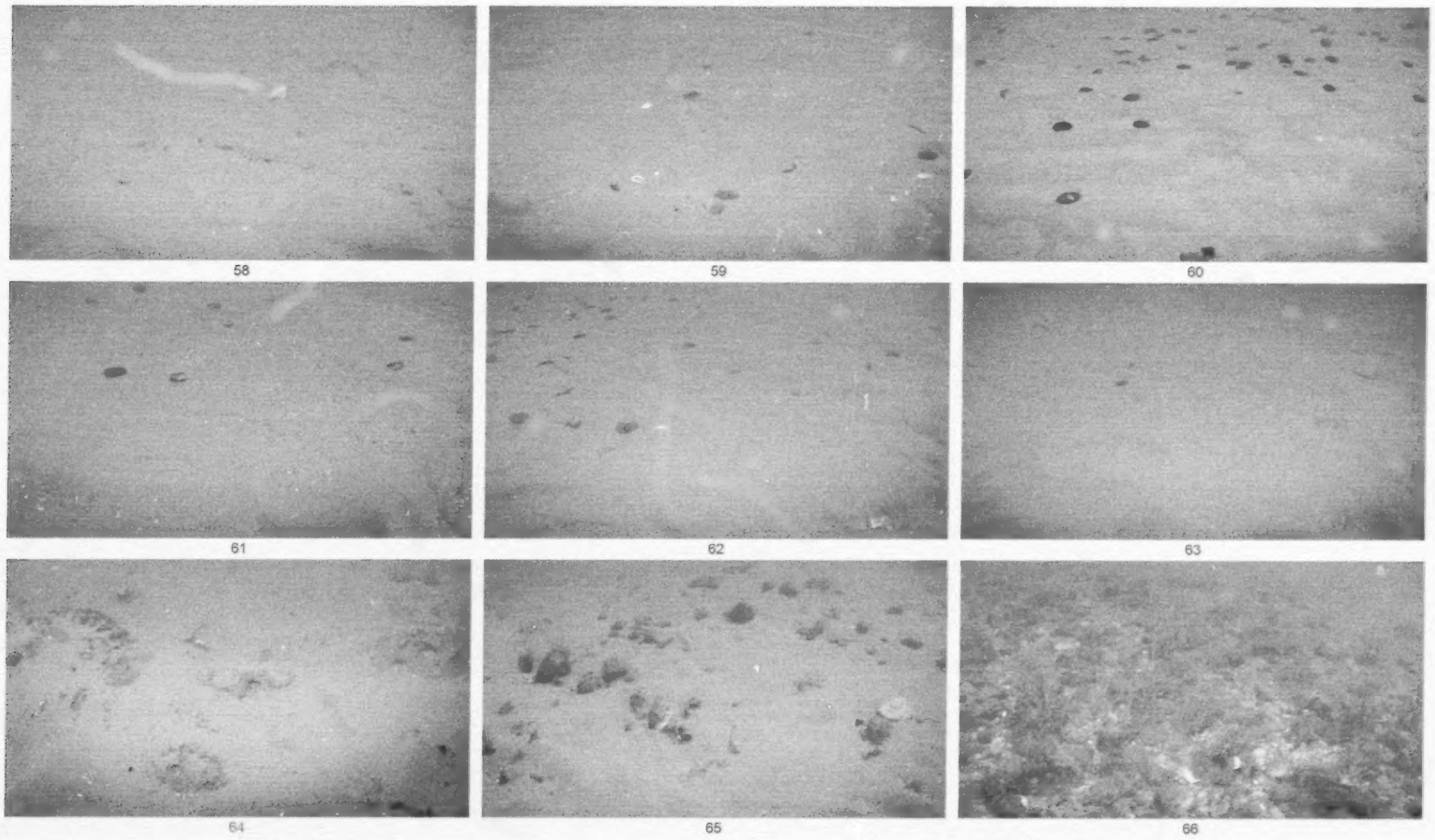

Figure 19. Bottom oblique imagery for area E. The western part of the area has gravel and other hard substrates (64, 65, 66) while sand dominates in the eastern part. Image width-to-length ratios have been adjusted to fit the page.